Up-down asymmetry of type I plasma waves in the equatorial electrojet region

S. Ravindran, B. V. K. Murthy

▶ To cite this version:

S. Ravindran, B. V. K. Murthy. Up-down asymmetry of type I plasma waves in the equatorial electrojet region. Annales Geophysicae, 1997, 15 (6), pp.774-778. hal-00316280

HAL Id: hal-00316280
https://hal.science/hal-00316280

Submitted on 1 Jan 1997

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Ann. Geophysicae 15, 774–778 (1997) © EGS – Springer-Verlag 1997

Annales Geophysicae

Up-down asymmetry of type I plasma waves in the equatorial electrojet region

S. Ravindran, B. V. K. Murthy

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum 695 022, India

Received: 5 June 1996 / Revised: 6 January 1997 / Accepted: 13 January 1997

Abstract. The up-down asymmetry of the type I plasma waves in the equatorial electrojet region during daytime is investigated. It is shown that the asymmetry is exhibited not only in the vertical direction but also is manifested in the oblique direction (24.6° off zenith). The results further indicate the effect of neutral winds on the phase velocities of type I plasma waves.

Introduction

Using the VHF backscatter radar with nearly vertically (~1° off zenith to satisfy aspect sensitivity) pointing antenna beam at Jicamarca, it has been reported that the radar signal returns corresponding to upward propagating type I waves are stronger and more common than the downward propagating type I waves in the daytime when the ambient primary electric field (E_y) is eastward and vice versa in the nighttime when E_y is westward (e.g. Fejer *et al*., 1976; Farley *et al*., 1978; Kudeki *et al*., 1985). Kudeki *et al*. (1985) explained the observed up-down asymmetry of type I waves as due to currents associated with large-scale primary waves and second harmonic distortion of these waves. Balsley (1970) has reported east-west asymmetry in the electron drift velocity observed at Jicamarca. Farley (1985) has suggested this asymmetry to be a geographical rather than a plasma effect.

Using the VHF radar at Trivandrum (8°33′N, 77°E, dip 0.5°N) with antenna beams which can be switched from 24.6° off zenith westwards, to zenith and to 24.6° off zenith eastwards, we have studied east-west asymmetry of type I plasma waves in addition to their up-down asymmetry. The east-west asymmetry in the strength of type I waves is interpreted as a manifestation of the up-down asymmetry. The results of this study are presented here.

Correspondence to: B. V. Krishna Murthy

VHF radar system at Trivandrum

The basic system details of the VHF radar operating at 54.95 MHz were presented in Reddy *et al*. (1987) and are not repeated here. In the present study, in place of the regular 16 × 4 Yagi antenna array with a fixed beam orientation of 30° off zenith westwards, we have used a 15 × 4 antenna array which has provision to switch the antenna beam in the east-west plane to three directions, namely 24.6° off zenith westwards and eastwards and zenith. The 15 × 4 Yagi antenna array uses interlaced phasing to achieve beam switching. The details of this antenna array are presented in Reddy *et al*. (1990). The beam width (2-way) of the oblique beams is ~3.3° and that of the vertical beam is ~3°.

Results and discussion

The VHF radar observations were carried out during daytime on four days, October 12, 1988, September 20, 1990, October 9, 1990 and January 5, 1993 using the three antenna beam orientations. All the four days are magnetically quiet days with an A_p index < 17. In the present study only Doppler spectra corresponding to type I plasma waves are considered. The presence of type I in the Doppler spectra is identified by the well-defined narrow peak at a frequency corresponding to a velocity close to ion acoustic velocity. The zeroth and first moments of the Doppler spectra (type I) are calculated which give the power of the signal return and mean Doppler frequency f_1 of the type I irregularities respectively.

Typical Doppler spectra observed with vertical and oblique antenna beams are shown in Figs. 1 and 2 respectively. In these figures, the peak corresponding to the type I Doppler frequency is indicated by an arrow.

In Fig. 1 both up-going (negative Doppler) and down-going (positive Doppler) type I waves are seen to be present except at 1010 hours when only the up-going wave is seen. When both are present (in the same Doppler spectrum) the peak power of the up-going

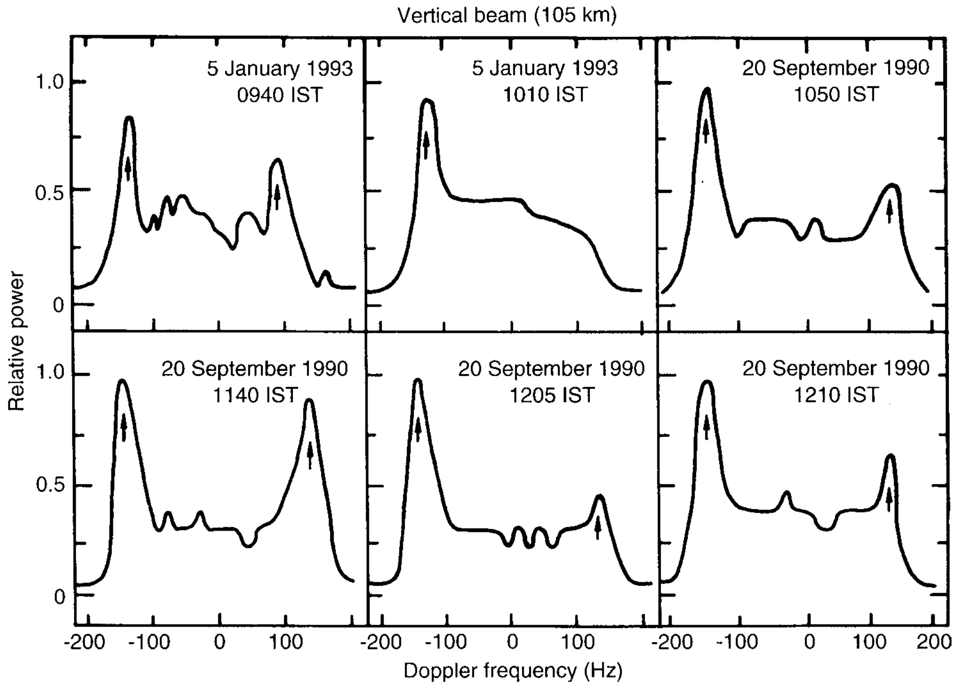

Fig. 1. Sample Doppler spectra for vertical antenna beam

waves is greater than that of the down-going waves. During daytime when the electron flow (and hence irregularity drift) is westward (corresponding to eastward E_y), the west-oriented beam will be seeing plasma waves with upward inclined propagation vectors along the line-of-sight and the east oriented beam those with downward inclined propagation vectors (Cohen and Bowles, 1967). From Fig. 2, it is clear that type I signatures appeared in the spectra corresponding to both the beams. However, the spectral peak corresponding to the west beam is generally stronger than that corresponding to the east beam.

The peak power and mean Doppler frequency of type I for the vertical beam at different times at three altitudes on September 20, 1990 are shown in Fig. 3a,b. It is clear that at the higher and lower altitudes of 108 and 102 km the up-going waves occur more frequently than the down-going ones whereas at 105 km the occurrences of the two are equal (Fig. 3a). Over the three altitudes, the up-going waves are (often) stronger than the down-going ones as indicated by the power of the signal return. No significant differences are seen, in general, between the mean Doppler frequency of the up and down-going waves (Fig. 3b). Similar features are revealed on the other three days of observations (not shown here).

The peak power and mean Doppler frequency corresponding to the west and east beams at different times on January 5, 1993 at three altitudes are shown in Fig. 4a,b respectively. The number of occurrences of type I waves is, in general, greater for the west beam than for the east beam (Fig. 4a). Considering the mean Doppler frequency (f_1), the variations are similar for the west and east beams and the values (of f_1) are nearly the same. At 104 km, while the variations of f_1 are similar, f_1 values are greater for the west beam than for the east beam at times later than 1000 h. The differences between the two reach values as high as 80 m/s (velocity scale is shown along the ordinate on the right hand side). At 107 km the behaviour of f_1 is somewhat similar to that at 104 km. Similar features are revealed on other three days of observations (not shown here). Considering all the four days of observations, it is seen that f_1 is different for west and east beams on a number of occasions.

The results for the four days of observations are summarized in Table 1, considering the data at the three altitudes. The number of occurrences (of type I) for the west beam (waves with upward inclined propagation vectors) are about 25% more than that for the east beam (waves with downward inclined propagation vectors). For the data of the vertical beam, the number of occurrences of up-going waves is about 77% greater than that of down-going waves. The number of cases in which the peak power P_I for up-going waves is greater than that for the down-going waves is more than the number of cases in which P_I for down-going is greater than that for up-going waves. In about 30% of the cases the two powers are same.

The results presented clearly bring out the preponderance of the occurrence of up-going type I plasma waves over the down-going waves in the daytime as well as that of upward inclined waves over the downward inclined waves. This difference is more marked for the vertical beam (upward and downward going waves) than for the west and east beams (waves with upward inclined and downward inclined propagation vectors). Further, the upward going (and upward inclined) waves are, in general, stronger than the downward going (and downward inclined) type I plasma waves.

Kudeki *et al.* (1985) showed from theoretical considerations that the up-down asymmetry of type I plasma waves is a consequence of the non-linear development of

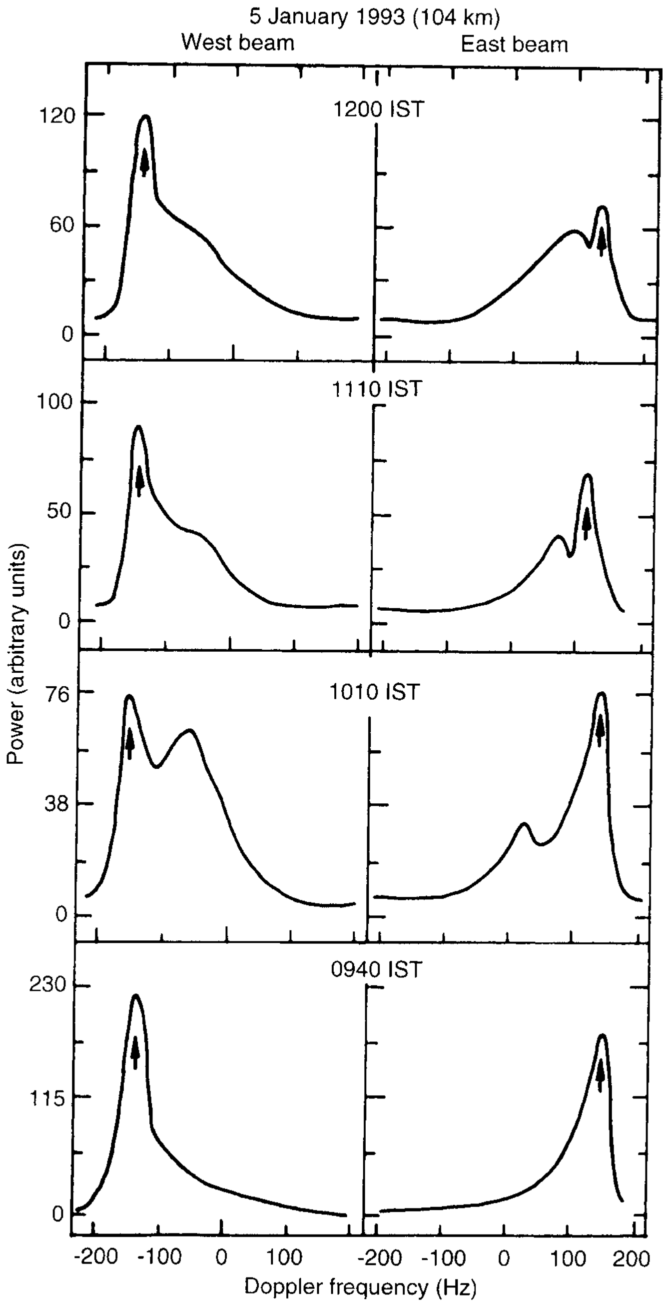

Fig. 2. Sample Doppler spectra for west and east antenna beam

the horizontally propagating large-scale primary waves. In the daytime equatorial electrojet, the vertical electron motion associated with the large-scale horizontally propagating primary wave causes a net downward motion of the electrons because the downward motion of the regions of enhanced electron density involves more electrons than the upward motion of the regions of depleted electron density. This net vertical motion would disappear in the presence of a balancing asymmetry in the vertical velocity waveform of the primary wave resulting in a reduction of the vertical polarization field. Such an asymmetry would lead to the preponderance of the up-going type I waves over the down-going waves. Further, Kudeki *et al.* (1985) have shown that the non-linear deformation of the perturbed vertical velocity of electrons (second harmonic distortion) accentuates this asymmetry.

The observations of up-down asymmetry of type I waves in the daytime presented are in accordance with the explanation of Kudeki *et al.* (1985). We have also shown that this asymmetry exists even when looking in an oblique direction (24.6° off zenith) with upward inclined waves being predominant over the downward inclined waves which is also in qualitative agreement with the explanation of Kudeki *et al.* (1985). However, the effect of reduction of vertical polarization field (due to large-scale primary waves as mentioned already) would be more on the vertical velocity of the electron velocity (relative to ions) than on the oblique components. Thus the up-down asymmetry can be expected to be more dominant in the vertical beam observations than in the oblique beam observations as observed in the present study.

It is seen in the present study that f_{I} is significantly more for the west-beam than for the east-beam on some occasions (e.g. on January 5, 1993, Fig. 4b). It is known that neutral winds affect the phase velocity of the type I waves (e.g. Fejer *et al.*, 1975; Cohen and Hooke, 1978). Neutral atmospheric motions including prevailing winds, atmospheric tides and atmospheric gravity waves can be expected to produce changes in the phase speed of the type I plasma waves (Cohen and Hookes, 1978). The observed phase speed (V_p) of the type I waves can be written as (Balsley *et al.*, 1976)

$$V_p = C_s + V_y \cos\theta$$

where C_s is the ion-acoustic speed, θ is the elevation and V_y is the zonal speed of neutral wind. Thus, the difference in the observed type I phase speeds in the east and west directions can be attributed to east-west asymmetry in the neutral motions. That is, the zonal wind at the observation volume seen by the radar for the east and west beams could be different. Balsley (1977) has also reported strong longitudinal non-uniformity in the neutral wind structure over Jicamarca. It may be noted that the horizontal separation of the observation volume of the east and west beams at 100 km altitude for the radar configuration in the present study is ~90 km. It is interesting note that the peak power P (for the same beam) has not shown in general significant differences (between west and east beam observations) in contrast to f_{I}. As neutral winds do not affect the strength of the type I waves (Fejer *et al.*, 1975), attributing the observed east-west differences in f_{I} to neutral (zonal) wind differences is consistent with this.

The phase velocity V_p data on January 5, 1993 (Fig. 4b) in the prenoon period (when the data is continuous) is subjected to fast Fourier transform (FFT) to delineate periodic components. It is found that V_p corresponding to both the beams reveals periodic components with periods of ~60 and ~30 min at all three altitudes with amplitudes ~10 m/s and 5 m/s respectively and no significant phase difference between corresponding periodic components from west and east beam data. The difference in the steady component is

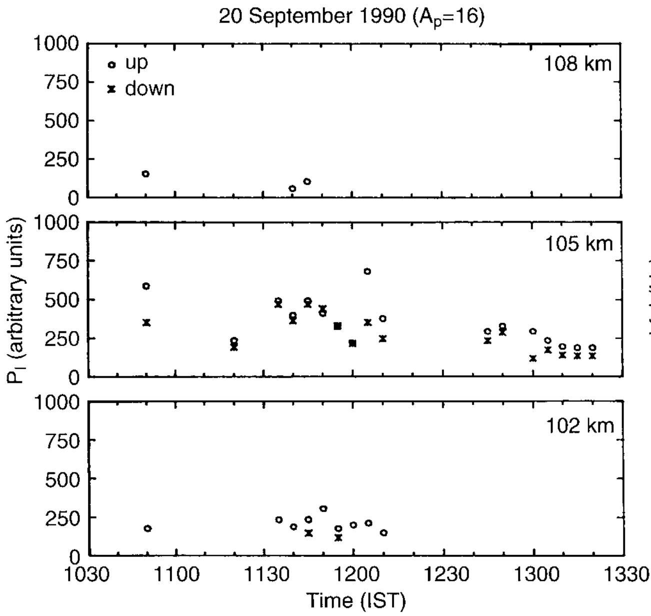

Fig. 3. Backscatter signal power and peak Doppler frequency for up-going and down-going type I plasma waves

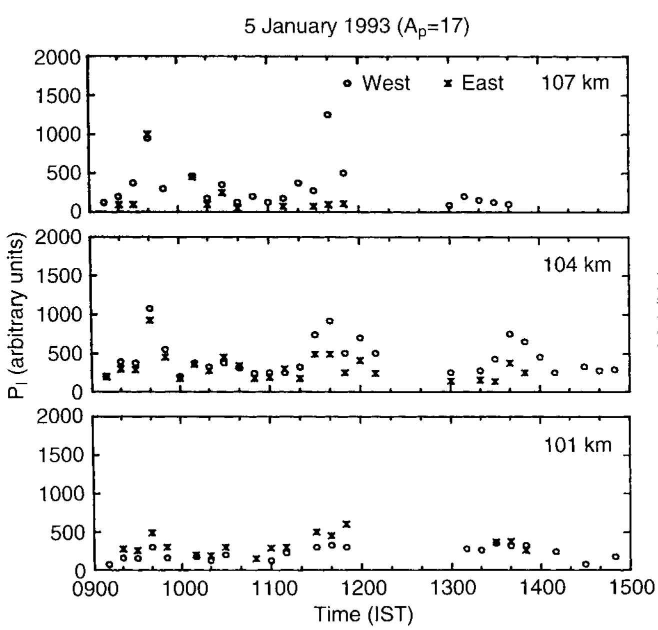

Fig. 4. Backscatter signal power and peak Doppler frequency for type I waves with upward inclined (west antenna beam) and downward inclined (east antenna beam) propagation vectors

Table 1.

Antenna position	Number of occurrences		Number of cases for which		
	Upgoing	Downgoing	$P_I(U) > P_I(D)$	$P_I(U) < P_I(D)$	$P_I(U) = P_I(D)$
E-W	164	131	54	31	38
V	62	35	21	3	10

$P_I(U)$, power in upgoing type I waves
$P_I(D)$, power in downgoing type I waves

$\sim$10 m/s which could be due to a longer period component (longer than the data length). These values appear to be reasonable to be attributed to the effect of neutral winds.

Acknowledgements. We wish to express our thanks to Dr CA Reddy for his involvement in the initial stages of this work. We thank Mr KV Janardhanan and his group in the Space Physics Laboratory for carrying out the VHF backscatter radar experiment. We thank Mr PG Jayaprakash for word processing of this paper.

Topical Editor D. Alcaydé Thanks M. A. Abdu and E. Kudeki for their help in evaluating this paper.

References

Balsley, B. B., A longitudinal variation of electron drift velocity in the equatorial electrojet, *J. Geophys. Res.*, **75,** 4291, 1970

Balsley, B.B., E-region dynamics, *J. Atmos. Terr. Phys.*, **39,** 1087–1096, 1977

Balsley, B. B., B. G. Fejer, and D. T. Farley, Radar measurements of neutral winds and temperatures in the equatorial E region, *J. Geophys. Res.*, **81,** 1457–1459, 1976

Cohen, R., and W. H. Hooke, Neutral atmospheric motions manifested in radar echo Doppler shifts from two-stream irregularities in the equatorial electrojet, *J. Geophys. Res.*, **83,** 4791–4797, 1978

Cohen, R., and K. L. Bowles, Secondary irregularities in the equatorial electrojet, *J. Geophys. Res.*, **72,** 885–894, 1967

Farley, D. T., Theory of equatorial electrojet plasma waves: new developments and current status, *J. Atmos. Terr. Phys.*, **47,** 729–744, 1985

Farley, D. T., B. G. Fejer, and B. B. Balsley, Radar observations of two dimensional turbulence in the equatorial electrojet, 3. Night time observations of type I waves, *J. Geophys. Res.*, **83,** 5625–5632, 1978

Fejer, B. G., D.T. Farley, B .B. Balsley and R. F. Woodman, Oblique VHF radar spectral studies of the equatorial electrojet, *J. Geophys. Res.*, **80,** 1307–1312, 1975

Fejer, B. G., D. T. Farley, B. B. Balsley, and R .F. Woodman, Radar observations of two-dimensional turbulence in the equatorial electrojet, 2, *J. Geophys. Res*, **81,** 130–134, 1976

Kudeki, E., D. T. Farley, and B. G. Fejer, Theory off spectral asymmetries and nonlinear currents in the equatorial electrojet, *J. Geophys. Res.*, **90,** 429–436, 1985

Reddy, C. A., B. T. Vikram Kumar, and K. S. Viswanathan, Electric fields and current in the equatorial electrojet deduced from VHF radar observations,1. A method of estimating electric fields, *J. Atmos. Terr. Phys.*, **49,** 183–191, 1987

Reddy, C. A., K. V.Janardhanan, K. K. Mukundan and K. S. V. Shenoy, Concept of an interlaced phased array for beam switching, *IEEE Trans. Antennas and Propag.*, **38,** 573–575, 1990